Notes on the Biology and Economic Importance of the Mango Weevil, Sternochetus mangiferae (Fabricius), in Hawaii (Coleoptera: Curculionidae)

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INTRODUCTION

The mango weevil, *Sternochetus mangiferae* (F.), is an important mango pest in the Hawaiian Islands, at times infesting nearly 100 percent of the seeds in certain areas. Because injury is confined almost entirely to destruction of the seed, important only to propagators of root stock, very little attention has been given to the control of this insect since it was first reported in Hawaii nearly 60 years ago (Van Dine, 1906).

DISTRIBUTION

The mango weevil is found in all the principal mango-producing areas in the world, with the exception of North, South, and Central America, and the Caribbean. It is probably native to southeast Asia, since this region is the reported home of the mango.

An early record by Simmons (1889–1891) mentioned the progressive spread of the insect throughout the mango-producing districts of India, and its occurrence at the time in the northern and western parts of Bengal. He marveled at its presence in the Isle of France (Mauritius) and Madagascar and wondered how it arrived there. Rutherford (1914) mentioned its presence in Ceylon and also added that in Labuan (British Straits Settlement) only 10 percent of the mangoes were edible, owing to attacks attributed to *S. mangiferae*.

Ramakrishna (1923) reported the insect in Madras but stated it was not a serious pest. Bainbridge and Fletcher (1917) recorded it from Mauritius, Reunion, Java, Chagos Islands, and Malaya. Leefmans (1927) cited its presence in the Philippines, Ceylon, and the Federated Malay States, and it was indicated in Zanzibar from weevil-infested mango seeds intercepted in Germany in bales of clove stems imported from Zanzibar (Hubenthal, 1915). Hargreaves (1923) noted it for the first time in Uganda, South Africa, and stated that it was of rare occurrence. The weevil was found in Hawaii in 1905 (Van Dine, 1906). In 1961, La Plante reported it to be established in Guam (personal communication from H. Ivan Rainwater, Plant Quarantine Division, USDA, Honolulu, Hawaii). The mango weevil is also found in Queensland, Australia (Jarvis, 1946).

The literature contains references to two other closely related weevils, *S. gravis* (F.) and *S. poricollis* (Faust), which appear to have been confused with *S. mangiferae* by some writers. *S. gravis* has been recorded from the Federated Malay States (Leefmans, 1927). Bainbridge and Fletcher (1917) reported that *S. gravis* replaced *S. mangiferae* in northeast India and was a serious pest in Bengal. They also reported the presence of *S. gravis* in Burma and Siam and stated that the mangoes in the government gardens at Maymyo, Burma, were heavily infested by this species. The larvae were heavily parasitized and the infested fruit did not ripen well and dropped prematurely. These same two authors noted that *S. poricollis* appeared to be confined to eastern Bengal and Assam, where at times it had been reported to destroy an entire mango crop.

LIFE HISTORY AND BIOLOGY

Literature on the ecology, life history, and biology of the mango weevil is scarce and confined for the most part to Indian and Dutch journals. Unfortunately, little of significance has been reported. Furthermore, published accounts contain ambiguous statements concerning *S. mangiferae*, *S. gravis*, and *S. poricollis*.

According to Rutherford (1914), *S. mangiferae* enters the seed in the early larval stage, feeds on the cotyledon, and transforms to pupa and adult within the seed. These observations agree with those of Van Dine (1906), Bainbridge and Fletcher (1917), Subramanyan (1925), Leefmans (1927), and Jarvis (1946). On the other hand, Lefroy and Howlett (1909) and Dammerman (1929) claimed that *S. mangiferae* pupates within the soil.

Leefmans (1927) stated that *S. mangiferae* and *S. gravis* were biologically distinct in that the former usually bored in the seed, whereas the latter developed in the flesh of the fruit, ate only the fibrous layer of the seed, and emerged from the fruit to pupate in the soil. In contradiction, Lefroy and Howlett (1909) claimed that larvae of both species fed in the seed and, when mature, ate through the pulp and emerged to pupate in the soil. Sen (1923) claimed that *S. gravis* pupated within the fruit in eastern and northern Bengal.

Bainbridge and Fletcher (1917) reported that the larvae of *S. poricollis* developed and pupated in the pulp and, in this respect seemed to differ from the other two species.

Jarvis (1946) reported that in Queensland, Australia, *S. mangiferae* usually laid only one egg on each young fruit and that the newly hatched larva tunneled directly to the seed, where it fed and developed to pupa and adult. He further noted that adults normally remained until the following fruiting season in the vicinity of the parent tree and that, as a result, dispersal of the pest occurred largely through transport of fruit and seeds from place to place. He considered that damage was of more concern to nurserymen than to fruit growers and thus control was impractical.

Subramanyan (1925) wrote that in Madras, India, adults of *S. mangiferae* were found feeding on leaves and tender mango shoots in March and April. Oviposition occurred during a period of 1 to 3 weeks, at first on the tender fruit and finally on half-grown fruit. The egg stage lasted 7 days, the pupal stage 7 days, and the total life cycle extended over a period of 50 days. Adult emergence from the seed was made from a hole cut through the concave edge of the epicarp.

The first published account of the life history of the mango weevil in Hawaii was by Van Dine (1906). By careful observation of the time of year when the weevils came out of hibernation and laid eggs on the fruit and when the different stages appeared in the seed, Van Dine estimated that the period required for development from egg to adult was 40 days.

Swezey (1935) found 10 percent of the seeds infested with larvae and pupae as early as January, which finding, in his opinion, demonstrated that adults did not need a long dormant period. He made periodic examinations of seeds over the years and found from 80 to nearly 100 percent of the seeds infested during the summer months (Swezey 1931, 1943, 1952).

Keiser (1959) found that weevil-infested seeds from one location progressively decreased from 95 percent in mid July to 41 percent in early September. During the same period, the percentage of larvae decreased from 100 to 25 and the percentage of adults increased from 0 to 50. He concluded from these trends that the maximum adult activity had occurred sometime prior to his first seed examination.

Life History in Hawaii

Newly formed adults are light red in color, which deepens gradually to dark red. In 3 to 4 days, the color changes to grayish black, and light-pink to brown diagonal markings appear on the head and across the wing covers, which are deeply ridged longitudinally. The adult is about 4.2 mm. wide by 8 mm. long. The male meso- and meta-thoracic ventrites are concave with sparse scales whereas those of the female are convex with numerous scales. The male pygidium is rounded at the apex and that of the female has an elevated ridge.

Caged adults are inactive during the day and crowd together in clusters in the corners of cages or conceal themselves in cavities and crevices. Adults are nocturnal and begin feeding, mating, and ovipositing at dusk, although mating has also been observed in cages during the day. Males and females mate more than once.

Caged adults feed readily on the pulp of mango seeds, as well as on mango fruit, apples, and raw peanuts. A diet of water, mango seeds, and mango fruit is sufficient for inducement of sexual maturity.

The mango weevil completes its entire development from newly hatched larva to adult within the seed. Adults cut their way out of the naked seed with their mouthparts, usually within a month or two after the fruit falls and decays. On rare occasions weevils may emerge from the seed before fruit fall and eat their way through the flesh of the ripe fruit, ruining it completely.

Weevil-emergence data from fruit collected in late April and held in laboratory cages showed that of 230 adults which developed in the seeds, 80 percent emerged in 22 to 76 days (fig. 1). The remaining adults were found dead in seeds cut open 7 months after the last weevil emerged.

Adults are capable of surviving long periods, even under unfavorable conditions. Pope (1929) recorded survival without food for 140 days in a cork-stoppered bottle. The authors have records of weevils that survived for 127 days without food or water and for 21 months with food and water.

Adults collected from the field in February required 11 to 40 days before they laid eggs. Newly transformed adults excised from seeds as pupae in July and September completed the preoviposition period in a minimum of 178 and a maximum of 204 days. Adults excised from seed following fruit fall in February, March, and April required a minimum of 56, 30, and 28 days, respectively, to complete the preoviposition period. Adults excised around the middle of May required a minimum of 308 days, and the period decreased gradually from 272 days in June to 91 days in December (fig. 2). Onset of oviposition occurred between January 30 and May 17, a range of only 3.5 months, which was surprising since weevils were excised from seeds following fruit fall over a period covering 10 months.

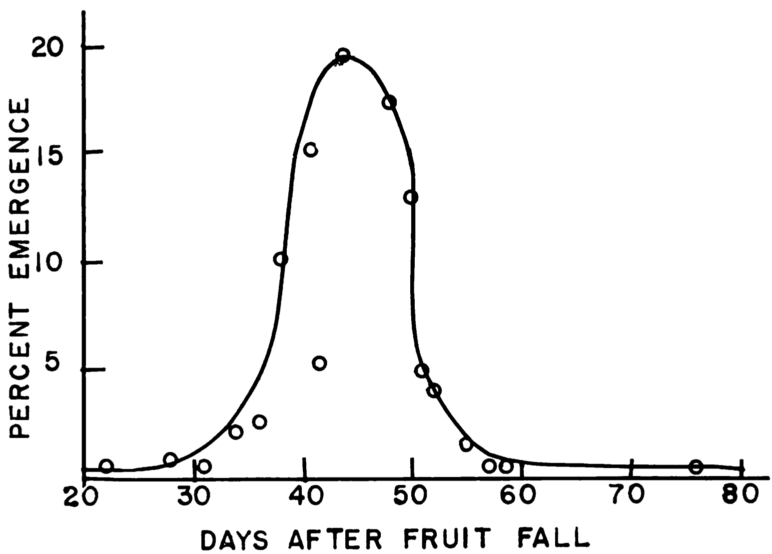

FIGURE 1. Time of mango weevil emergence from mango seeds following fruit fall.

The wide range in preoviposition period and the comparatively narrow interval for onset of oviposition might be explained by photoperiodism. Adults developing in May or later appear to go into diapause, which is broken around the first of the year. The break is timed with onset of the regular mango fruiting season. Onset of diapause seems to be associated with a long-day photoperiod, and break of diapause with a short-day photoperiod, in contrast to the response of the European corn borer, *Ostrinia nubilalis* (Hubner), and other insects (Beck, 1963).

A few adults have been observed to live through two seasons with a hibernation period between. Females in one lot of adults removed from seeds in July and continuously provided mango-seed pulp, water, and mango fruit for oviposition did not lay eggs until February of the following year, or a period of 217 days. These females then continued to oviposit until the middle of June. Five males and eight females from this lot were still alive by the following March, when the females began ovipositing again. This time the resting period covered 281 days. Viable eggs were produced from March until early in June, when egg laying ceased. The last female died late in June after a life span of more than 21 months.

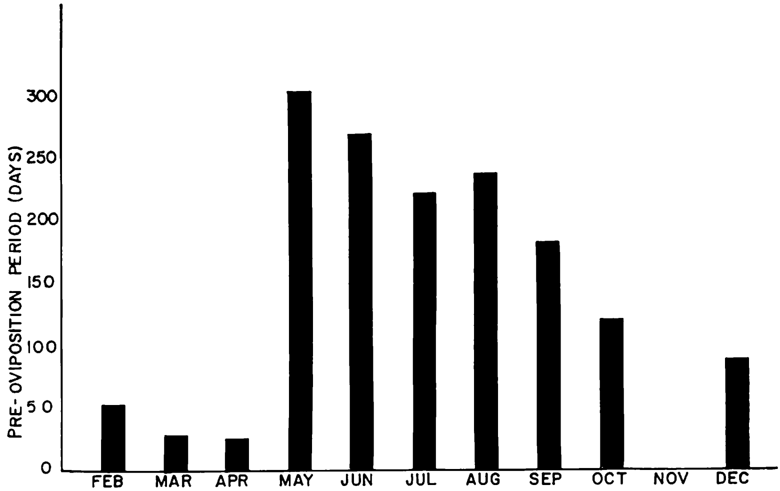

FIGURE 2. Pre-oviposition periods of adults excised from mango seeds of fruits developing in various months of year (1957–1958).

Mango trees bear fruit at different times in different areas and often produce two crops a year, the spring-into-summer crop and a light off-season crop that appears in the winter months; thus, at least a few fruits are present in one location or another during almost every month in the year.

During nonfruiting periods, weevils hibernate by the hundreds in crevices of fences and stone walls near mango trees (Van Dine, 1906). The authors have found large numbers concealed under loose bark on mango tree trunks as high as 15 feet and hidden in branch terminals. They also found that large numbers could be obtained during the early mango-fruiting period by shaking limbs over canvas.

When disturbed, adults drop immediately and remain motionless. They possess well-developed wings and should be capable of flight, but flight has not been observed. It undoubtedly occurs, since McBride (1935) caught adults during January and February in invaginated glass fruit fly traps baited with fermenting lure. Infrequently single specimens, or rarely two, have also been taken in ultraviolet traps (personal communication from J. W. Beardsley, University of Hawaii, Honolulu).

Egg Stage. Eggs are laid singly on all areas of the skin and at times on the stems of small- to medium-sized fruit, often on mature fruit. In the laboratory, females have been observed ovipositing in subdued light in the early morning brownish exudate from her abdomen over the egg and by means of sideward and in the early evening after dusk. The female first makes a shallow, abraded depression in the skin of the mango, then after laying an egg, she emits a movements of the ovipositor sheath covers it completely with the exudate. With her mouthparts, she then makes a crescent-shaped cut in the mango about 0.25 to 0.50 mm. from the posterior end of the egg. The cut in the mango causes a copious flow of sap, which in time solidifies and covers the egg with a protective opaque coating.

In order to determine egg hatch, ovipositing females were caged with a supply of mangoes overnight. Eggs were removed, placed on moist blotting paper in petri dishes, and observed until they hatched. During the hatching period, more than 180 eggs were observed. Eggs hatched in 7 days in March and early April when daily temperatures fluctuated between 65 and 86° F., and in 5 to 6 days in late May and June when temperatures were a few degrees higher.

Oviposition records of five individual females showed that a single female may lay as many as 15 eggs in one day and a maximum of nearly 300 over a 3-month period. Hatch ranged from 40 to 68 percent, which did not represent the full reproductive potential since 67 percent of the oviposition sites contained only the lower half of the egg cast formed by the exudate with which females cover eggs (table 1). These cast remnants indicated that the eggs had been destroyed either accidentally or through cannibalism by the weevils. Four ovipositing females died two to three weeks after oviposition ceased; one failed to oviposit.

Table 1. Individual longevity, oviposition, and egg records of five mango weevil females.

Female*	Days Lived	Laying Period (Days)	No. of Eggs Laid	Percent Hatch	Average No. Eggs Per Day	Maximum No. Eggs Per Day	No. of Eggs Destroyed
1	98	—	—	—	—	—	—
2	124	76	281	43	3.7	15	573
3	100	90	205	40	2.2	11	517
4	110	90	245	68	2.7	13	523
5	Escaped	40	147	42	3.7	12	203

* Females numbers 1 to 3 isolated with one male each and numbers 4 and 5 with two males each after egg laying was observed.

Larval Stage. Immediately after it hatches, a young larva enters the fruit directly by cutting a hole through the chorion of the egg on the side in contact with the fruit. At time of hatch the larva is approximately 1 mm. long and 0.15 mm. wide. The larva burrows through the flesh, usually directly to the seed. Occasionally, the authors have observed that the tunnels, which proceeded downward for a short distance, changed direction laterally and then continued to the seed. Fresh larval entry to the seed is indicated by a small discolored area. As fruit and seed develop, the tunnel and seed entry are completely obliterated so that in time it is impossible to determine infested from noninfested seeds unless they are cut. The time taken by the larva to reach the seed after hatching from the egg must be very short as indicated from measurements of head capsules of larvae found in various locations in fruit (table 2). The minimum observed period for larvae to penetrate the seedcoat was less than one day.

Table 2. Head capsule widths of larvae dissected from various locations in mangoes.

Location	Number Measured	Width of Head Capsule (mm.)	
		Maximum	Minimum
Egg	3	0.15	0.10
Skin of fruit	3	0.15	0.14
Seedcoat (in fibrous layer)	4	0.25	0.16
Seedcoat	48	1.00	0.12
Seed (newly entered)	5	0.43	0.20
Seed (feeding)	52	1.50	0.30

Larvae pass through at least five instars as shown by measurements of the widths of head capsules of nine individual larvae following several successive molts (table 3). Measurements of head capsules from 479 larvae of varying sizes showed that widths ranged from 0.1 to 1.5 mm. and were distributed as shown in figure 3. Distribution peaks, near widths of 0.1, 0.15, 0.2, 0.3, 0.55, 0.95, and 1.33 mm., could indicate the possibility of seven instars, although many more measurements would be needed to verify this finding.

Young larvae, 2 to 3 mm. in length, are frequently found in the seed. On one occasion a larva slightly under 2 mm. in length was cut from the seed of a fruit caged on the tree with gravid weevils 12 days earlier and reared to the pupal stage 15 days later. At prevailing temperatures (70° to 85° F.), about 5 days would have been required for egg hatch, which would place the age of the larvae when removed from the seed at 7 days and the duration of the larval stage at approximately 22 days.

The ability of larvae to infest mango seeds may be associated, in part, with the rate the seedcoat hardens. The seedcoat is extremely soft in very young fruits of all varieties, which makes the seeds susceptible to larval penetration. As fruit develops, the seedcoat hardens, and in some varieties, such as Itamaraca, the seedcoat is quite hard when the fruit is still young.

In one test, a small Itamaraca mango fruit was caged on the tree for six weeks

Table 3. Increase in width of larval head capsules following one or more successive molts.

Larva No.	Width (mm.) of Head Capsule at Indicated Probable Instar				
	1	2	3	4	5
1	0.15	0.20	—	—	—
2	—	—	0.5	0.8	1.0
3	—	—	0.55	0.8	—
4	—	—	—	0.85	1.35
5	—	—	—	1.0	1.25
6	—	—	—	1.0	1.30
7	—	—	—	—	1.0 →pupa
8	—	—	—	—	1.25→pupa
9	—	—	—	—	1.25→pupa

to prevent weevil infestation. At the end of this period, 10 weevils were introduced and removed after 4 days. The fruit was picked two weeks later; it had 15 eggs and numerous punctures. An examination revealed almost complete hatch of eggs and much larval tunneling in the flesh, especially near the very hard seed. None of the larvae had entered the seed and none were found alive or dead in pulp. Presumably death had occurred when the larvae were very small; all but

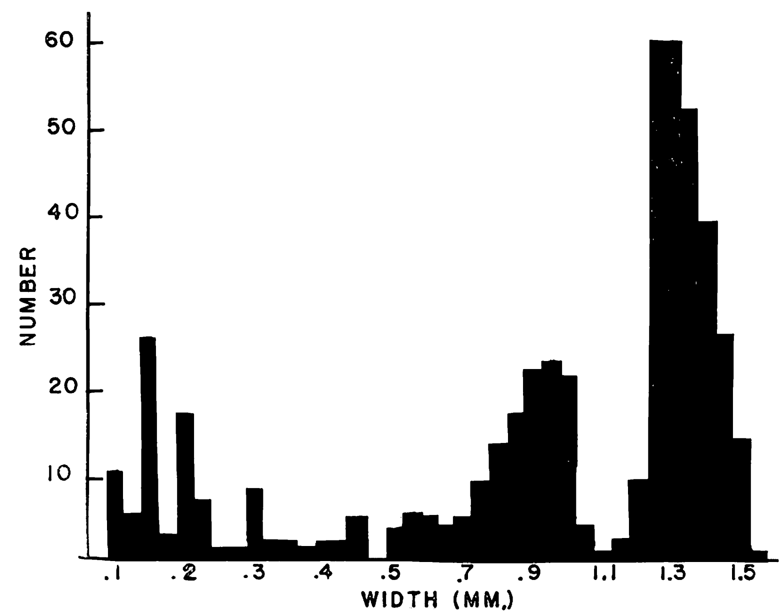

FIGURE 3. Distribution of head capsule widths of mango weevil larvae.

the minute sclerotized segments had been destroyed by proteolysis, which made larval recovery difficult.

It has been observed that so-called wild mangoes, of which several different types are found in Hawaii, appeared much more susceptible to weevil attack than Pirie or Haden, the two most frequently grown commercial varieties. Examination in 1960 of approximately 100 seeds of each kind of fruit showed common (wild) mangoes with 93 percent of the seeds infested, Chinese (wild) with 53 percent, Pirie 37 percent, and Haden 22 percent. The first three types of fruit were collected at the same time and place at sea level on Oahu. Haden was collected at Poamoho at a considerably higher altitude where few mangoes are found and weevil populations are low.

Swezey (1922) commented on the failure of a large proportion of eggs laid on fruit to complete development to adults. He removed three pupae from a mango seed taken from a mango that had 31 egg punctures when it fell from the tree. He found punctures numerous on many mangoes, but never more than two or three weevils per fruit.

In 1957 the authors examined 1,158 seeds from fruit in four locations and found 6 percent with no infestation, 69 percent with one weevil per seed, 19 percent with two, 5 percent with three, 0.6 percent with four, and only 0.3 percent with five weevils. In other laboratory investigations as many as six weevils in various stages of development were found in one seed.

In three of the above-mentioned locations, counts were made on fruits of varying ripeness to compare the number of oviposition scars per fruit with the number of weevils per seed. There appeared to be no direct relationship between weevil infestation and the number of oviposition scars. The average number of scars ranged from 1.7 per green fruit to 9.5 per ripe fruit, and the average number of weevils per seed from 1 to only 1.6. It would appear that weevils continue to oviposit as the fruit develop, but larvae from eggs deposited during the later stages of fruit development are unable to penetrate the seed.

Pupal Stage. Pupation occurs within the seed. Full-grown larvae removed from seeds have been observed to complete the change to the pupal stage in approximately 6 hours. Duration of the pupal period was observed to be about 7 days at a mean temperature during May of 74° F. When first formed, pupae are almost pure white. Just before the end of the pupation period the color changes to a very light red; within 6 to 7 hours after changing color the pupa changes to an adult. On one occasion a larva was found pupating in the flesh of the mango; the extensive tunneling and decay caused by its feeding and the absence of an exit hole in the seed proved conclusively that the larva had developed entirely in the pulp of the mango (Balock, 1961).

Relation of Mango Drop to Weevil Infestation

Pope (1924) and Subramanyan (1927) attributed heavy drop of immature mangoes to weevil attack. Van Dine (1906) and Swezey (1931, 1943) concluded that weevil infestation did not cause premature dropping, nor was it detrimental to fruit quality. Voute (1935) theorized that premature fruit drop was associated with over-production, and dropping was a natural phenomenon that prevented overloading of the trees. However, he expressed the opinion that infested fruit were unfit to eat.

L. F. Steiner and Frank S. Morishita, Entomology Research Division, USDA (unpublished data 1951), while field testing insecticides on Molokai against the oriental fruit fly, *Dacus dorsalis* Hendel, sampled 4,000 pounds of ripe mangoes picked at maturity and 1,200 pounds of ground fruit. They found seeds of the picked fruit to be 55 to 67 percent infested and the fruit of larger average size than ground fruit in which seeds were only 33 to 53 percent infested. Infested seeds contained from one to six weevils in larval, pupal, and adult stages.

The authors, in support of the conclusions of Van Dine, Swezey, and Steiner, observed that mangoes were not adversely affected by infestation except in the single fruit in which a larva had fed and pupated in the flesh, or in the rare cases when they emerged from seeds and tunneled through the pulp. However, detailed studies to determine possible differences in the taste and quality of infested and non-infested mangoes were not made. A comparison of weevil infestation in seeds of picked and fallen fruit from three locations on Oahu showed an infestation of 66 percent in fallen fruit and 76 percent in tree fruit.

HOST RANGE

We have no records of the mango weevil developing in any fruit but mango nor, to our knowledge, have any reports appeared in the literature regarding any other hosts. In the laboratory, we obtained forced oviposition on Irish potato, peach, litchi, plum, string bean, as well as on several varieties of apple. Weevils oviposited freely on potato and larvae tunneled for short distances in the flesh, but eventually tunnels and larvae disappeared and the infestation failed to develop. Only a few eggs were laid on the other materials tested.

ECONOMIC IMPORTANCE

It would seem safe to assume that most growers of commercial mangoes in Hawaii do not consider the mango weevil a serious threat to mango production, though it is of much consequence to shippers interested in export of fresh mangoes to mainland markets. At present, export is impossible because of quarantine restrictions on the shipment of weevil-infested fruit.

Individuals interested in lifting the mango quarantine have expressed the view that the weevil is not an economic pest of mangoes because of its record under Hawaiian conditions since 1906. However, contradictory statements in the literature concerning the pest status of *S. mangiferae* in India suggest that the weevil might behave differently in different environments, although this appears highly improbable. In attempting to predict pest potential in different areas, it would seem very important to know whether Indian entomologists, who reported serious injury to mangoes by *S. mangiferae*, were discussing this insect or *S. gravis* or *S. poricollis*, both of which have been regarded by some writers to be biologically different from *S. mangiferae* and much more injurious.

CONTROL

Destruction of immature stages in their protected position within the seed would appear impractical in the field except with systemic insecticides. On the other hand, the habit of hibernating as adults in loose bark on trunks of mango trees during nonfruiting periods would make them most vulnerable during this period to contact insecticides, chemosterilants, or possibly pathogens.

Nothing is known about the movement of weevils. Records show that high infestations appear year after year in some locations and low infestations appear in other locations, indicating that movement of adults may be restricted. This possibility of restricted movement should be more thoroughly investigated, and if found to be correct, complete control in commercial mango plantings might be obtained with effective pesticides applied during weevil dormancy and just prior to mango blossoming and fruiting. Steiner and Morishita (unpublished data, 1951) found that DDT, EPN, Dilan®[1], parathion, and parathion plus hydrolyzed protein were ineffective in reducing weevil infestation when applied biweekly to mangoes during ripening periods that extended over two months.

Of several methods tested at this laboratory for the quarantine treatment of fresh mangoes for export, gamma radiation was found to be the most effective medium for killing or sterilizing weevils within fruit. Methyl bromide fumigation under normal atmospheric pressure at a dosage of two pounds per 1,000 cubic feet for 8 hours at 70° F. gave complete kill of all stages, but injured the fruit. In a vacuum of 27 inches, dropping to 15 inches, in a 2-hour fumigation at 70 to 80° F., a dosage of two pounds per 1,000 cubic feet killed 95 percent of the adults and 100 percent of the larvae and pupae. Tolerance of fruit to treatment was not determined. Ethylene dibromide and ethylene chlorobromide tested as fumigants or aqueous dips were considerably less effective. Vicane® (Sulfuryl fluoride) was not effective (unpublished data, 1955–1961). Low-temperature storage at 10° F. for 5 days or at 20° F. for 24 days killed all weevil stages within seeds (McBride and Mason, 1934), but this treatment injured fruit.

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[1] A mixture of 1 part of 1,1-bis(*p*-chlorophenyl)-2-nitropropane (Prolan®) and 2 parts of 1,1-bis (*p*-chlorophenyl)-2-nb(Bitroutane ulan®).

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